CLAIMS

1. An optical device that connects, by a signal beam, between an externally inputted input signal and an output signal to be outputted, the optical device comprising:

an optical transmission line being sheet-form and including a refractive index distribution such that a highest refractive index part is provided in a direction of a thickness of the sheet and a refractive index does not increase with distance from the highest refractive index part in the direction of the thickness,

wherein a signal beam corresponding to the input signal is made incident on the optical transmission line as an incident beam,

wherein inside the optical transmission line, the incident beam is transmitted, in a direction of a length that is orthogonal to the direction of the thickness, in multiple modes having a plurality of eigenmodes in a direction of a width that is orthogonal to both the direction of the length and the direction of the thickness, and an exiting beam is generated by the plurality of eigenmodes interfering with each other in the direction of the length, and

wherein the exiting beam is made to exit from the optical transmission line, and the output signal corresponding to the exiting beam is outputted.

2. An optical device according to claim 1, wherein the optical transmission line has a size, in the direction of the length,

expressed by a function of a difference between a propagation constant of a 0th-order mode excited in the direction of the width of the optical transmission line and a propagation constant of a primary mode.

3. An optical device according to claim 1, wherein the optical transmission line has a size, in the direction of the length, expressed by a function of a basic mode width in the direction of the width, the highest refractive index in the direction of the thickness and a wavelength of a beam transmitted in the multi-mode optical transmission line.

4. An optical device according to claim 1, wherein the optical transmission line includes a refractive index distribution such that a central position in the direction of the thickness has the highest refractive index and the refractive index does not increase with distance from the central position.

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5. An optical device according to claim 4, wherein the refractive index distribution changes substantially along a quadratic function.

6. An optical device according to claim 4, wherein the optical transmission line is made of polysilane.

7. An optical device according to claim 6, wherein the optical transmission line is made of polysilane, and the refractive index distribution is provided by an oxygen concentration distribution when the polysilane is cured.

8. An optical device according to claim 1, wherein the input signal is an electric signal, and an incident portion is provided that converts the electric signal into the signal beam and makes the signal beam incident on the optical transmission line as the incident beam.

9. An optical device according to claim 8, wherein the incident portion has a plurality of light emitting portions disposed in an array in the direction of the width of the optical transmission line.

10. An optical device according to claim 1, wherein the input signal is a signal beam, and an incident portion is provided that makes the signal beam incident on the optical transmission line as an incident beam.

11. An optical device according to claim 1, wherein the output signal is an electric signal, and an exit portion is provided that receives the signal beam as an exiting beam having exited from the optical transmission line and converts the signal beam

into the electric signal.

12. An optical device according to claim 11, wherein the exit portion has a plurality of light receiving portions disposed in an array in the direction of the width of the optical transmission line.

13. An optical device according to claim 1, wherein the output signal is a signal beam, and an exit portion is provided that makes the signal beam exit from the optical transmission line as an exiting beam.

14. An optical device according to claim 1, wherein the optical device is a 1×N optical splitting device that is capable of receiving at least one input signal and outputting the input signal as a number, N (N=1,2,3,...), of output signals, and

wherein the optical transmission line includes:

an incident surface for making the incident beam incident; and

an exit surface for making the exiting beam exit,

the size in the direction of the length is a value that is substantially an integral multiple of the following expression when the basic mode width in the direction of the width is W_0, an effective refractive index of a 0th-order mode beam excited in the direction of the width is n_0 and the wavelength of the beam

transmitted in the multi-mode optical transmission line is λ, and

one incident beam is made incident on a center in the direction of the width on the incident surface and a number, N, of exiting beams are generated symmetrically with respect to the center in the direction of the width on the exit surface:

$$\frac{1}{N} \bullet \frac{n_0 W_0^2}{\lambda}$$

15. An optical device according to claim 1, wherein the optical device is an N×1 optical combining device that is capable of receiving a number, N (N=1,2,3,...), of input signals and outputting the input signals as at least one output signal, and

wherein the optical transmission line includes:

an incident surface for making the incident beam incident;, and

an exit surface for making the exiting beam exit,

the size in the direction of the length is a value that is substantially an integral multiple of the following expression when the basic mode width in the direction of the width is W_0, an effective refractive index of a 0th-order mode beam excited in the direction of the width is n_0 and the wavelength of the beam transmitted in the multi-mode optical transmission line is λ, and

a number, N, of incident beams all having the same wavelength λ are made incident symmetrically with respect to a center in the direction of the width on the incident surface and one exiting

beam is generated at the center in the direction of the width on the exit surface:

$$\frac{1}{N} \bullet \frac{n_0 W_0^2}{\lambda}$$

16. An optical device according to claim 1, wherein the optical device is a straight sheet bus that is capable of receiving a number, N (N=1,2,3,...), of input signals and outputting the input signals as a number, N, of output signals corresponding one-to-one to the input signals, and

wherein the optical transmission line includes:

an incident surface for making the incident beam incident; and

an exit surface for making the exiting beam exit,

the size in the direction of the length is a value that is substantially an integral multiple of the following expression when the basic mode width in the direction of the width is W_0, an effective refractive index of a 0th-order mode beam excited in the direction of the width is n_0 and the wavelength of the beam transmitted in the multi-mode optical transmission line is λ, and

a number, N, of incident beams all having the same wavelength λ are made incident on given positions in the direction of the width on the incident surface and a number, N, of exiting beams corresponding one-to-one to the number, N, of incident beams are generated in positions, on the exit surface, whose positions in

the direction of the width are the same as incident positions of the incident beams:

$$\frac{8n_0W_0^2}{\lambda}$$

17. An optical device according to claim 1, wherein the optical device is a cross sheet bus that is capable of receiving a number, N (N=1,2,3,...), of input signals and outputting the input signals as a number, N, of output signals corresponding one-to-one to the input signals, and

wherein the optical transmission line includes:

an incident surface for making the incident beam incident; and

an exit surface for making the exiting beam exit,

a size in the direction of the length is a value that is substantially an odd multiple of the following expression when the basic mode width in the direction of the width is W_0, an effective refractive index of a 0th-order mode beam excited in the direction of the width is n_0 and the wavelength of the beam transmitted in the multi-mode optical transmission line is λ, and

a number, N, of incident beams all having the same wavelength λ are made incident on given positions in the direction of the width on the incident surface and a number, N, of exiting beams corresponding one-to-one to the number, N, of incident beams are generated in positions, on the exit surface, whose positions in

the direction of the width are symmetrical to incident positions of the incident beams with respect to the center in the direction of the width:

$$\frac{4n_0W_0^2}{\lambda}$$

18. An optical device according to claim 1, wherein the optical device is a star coupler that receives a number, N (N=1,2,3,...), of input signals and outputs the input signals as a number, N, of output signals corresponding to the input signals, and

wherein the optical transmission line includes:

an incident surface for making the incident beam incident; and

an exit surface for making the exiting beam exit,

a size in the direction of the length is substantially a value of the following expression when the basic mode width in the direction of the width is W_0, an effective refractive index of a 0th-order mode beam excited in the direction of the width is n_0 and the wavelength of the beam transmitted in the multi-mode optical transmission line is λ, and

a number, N, of incident beams all having the same wavelength λ are made incident on predetermined positions in the direction of the width on the incident surface and a number, N, of exiting beams are generated for any one of the incident beams in positions,

on the exit surface, whose positions in the direction of the width are symmetrical to incident positions of the incident beams with respect to the center in the direction of the width:

$\left(p \pm \frac{1}{N}\right)\frac{4n_0W_0^2}{\lambda}$ (p is an integer that makes the value inside the parentheses positive)

19. An optical device according to claim 18, wherein the optical device is a star coupler that receives a number, N_{EVEN} (N_{EVEN}=2,4,6,...), of input signals and outputs the input signals as a number, N_{EVEN}, of output signals corresponding to the input signals, and

wherein the optical transmission line makes a number, N_{EVEN}, of incident beams all having the same wavelength λ incident on positions symmetrical with respect to the center in the direction of the width on the incident surface.

20. An optical device according to claim 18, wherein the optical device is a star coupler that receives a number, N_{ODD} (N_{ODD}=1,3,5,...), of input signals and outputs the input signals as a number, N_{ODD}, of output signals corresponding to the input signals, and

wherein the optical transmission line makes a number, N_{ODD}, of incident beams all having the same wavelength λ incident on positions asymmetrical with respect to the center in the direction

of the width on the incident surface.

21. An optical device according to claim 1, wherein the optical device is a two-way straight sheet bus that is capable of receiving a number, N (N=1,2,3,...), of input signals and outputting the input signals as a number, N, of output signals corresponding one-to-one to the first input signals, and is capable of receiving a number, M (M=1,2,3,...), of input signals and outputting the input signals as a number, M, of output signals corresponding one-to-one to the input signals, and

wherein the optical transmission line includes:

a first surface formed at one end in the direction of the length; and

a second surface formed at another end in the direction of the length,

a size in the direction of the length is a value that is substantially an integral multiple of the following expression when the basic mode width in the direction of the width is W_0, an effective refractive index of a 0th-order mode beam excited in the direction of the width is n_0 and the wavelength of the beam transmitted in the multi-mode optical transmission line is λ,

a number, N, of incident beams all having the same wavelength λ are made incident on given positions in the direction of the width on the first surface and a number, N, of exiting beams corresponding one-to-one to the number, N, of incident beams are

generated in positions, on the second surface, whose positions in the direction of the width are the same as incident positions of the incident beams, and

a number, M, of incident beams all having the same wavelength λ as the incident beams on the first surface are made incident on given positions in the direction of the width on the second surface and a number, M, of exiting beams corresponding one-to-one to the number, M, of incident beams are generated in positions, on the first surface, whose positions in the direction of the width are the same as incident positions of the incident beams:

$$\frac{8n_0W_0^2}{\lambda}$$

22. An optical device according to claim 1, wherein the optical device is a two-way cross sheet bus that is capable of receiving a number, N (N=1,2,3,...), of first input signals and outputting the input signals as a number, N, of first output signals corresponding one-to-one to the first input signals, and is capable of receiving a number, M (M=1,2,3,...), of second input signals and outputting the input signals as a number, M, of output signals corresponding one-to-one to the second input signals, and

wherein the optical transmission line includes:

a first surface formed at one end in the direction of the length; and

a second surface formed at another end in the direction of

the length,

a size in the direction of the length is a value that is substantially an odd multiple of the following expression when the basic mode width in the direction of the width is W_0, an effective refractive index of a 0th-order mode beam excited in the direction of the width is n_0 and the wavelength of the beam transmitted in the multi-mode optical transmission line is λ,

a number, N, of incident beams all having the same wavelength λ are made incident on given positions in the direction of the width on the first surface and a number, N, of exiting beams corresponding one-to-one to the number, N, of incident beams are generated in positions, on the second surface, whose positions in the direction of the width are symmetrical to incident positions of the incident beams with respect to the center in the direction of the width, and

a number, M, of incident beams all having the same wavelength λ are made incident on given positions in the direction of the width on the second surface and a number, M, of exiting beams corresponding one-to-one to the number, M, of incident beams are generated in positions, on the first surface, whose positions in the direction of the width are symmetrical to incident positions of the incident beams with respect to the center in the direction of the width:

$$\frac{4n_0W_0^2}{\lambda}$$

23. An optical device according to claim 1, wherein the optical transmission line includes: a reflecting surface that is formed at one end in the direction of the length and bends an optical path of the incident beam incident in a direction parallel to the direction of the thickness, substantially 90 degrees in the direction of the length; and/or a reflecting surface that is formed at another end in the direction of the length and bends an optical path of the exiting beam transmitted in the direction of the length, substantially 90 degrees so as to exit in a direction parallel to the direction of the thickness.

24. An optical device according to claim 1, wherein the optical transmission line includes: a prism that is formed at one end in the direction of the length and bends, in the direction of the length, an optical path of the incident beam incident in a direction inclined in the direction of the thickness; and/or a prism that is formed at another end in the direction of the length and bends an optical path of the exiting beam transmitted in the direction of the length, so as to exit in a direction inclined in the direction of the thickness.

25. An optical device according to claim 1, wherein the optical transmission line has a plurality of eigenmodes in the direction of the thickness.

26. An optical device according to claim 1, wherein the optical transmission line has a thickness of not less than 20 μm.

27. An optical device according to claim 1, wherein the optical transmission line is curved so that a central position in the direction of the thickness always draws the same curve on given two different cross sections including the direction of the length and the direction of the thickness.

28. An optical device according to claim 1, wherein the optical transmission line is twisted so that a central position in the direction of the thickness draws different curves on given two different cross sections including the direction of the length and the direction of the thickness.

29. An optical integrated device that connects, by a signal beam, between an externally inputted input signal and an output signal to be outputted, the optical integrated device comprising:

a light transmitting portion comprising a plurality of optical transmission lines being sheet-form and including a refractive index distribution such that a highest refractive index part is provided in a direction of a thickness of the sheet and a refractive index does not increase with distance from the highest refractive index part in the direction of the thickness, the optical

transmission lines being laminated in the direction of the thickness,

wherein a signal beam corresponding to the input signal is made incident on the optical transmission lines as an incident beam,

wherein inside the optical transmission lines, the incident beam is transmitted, in a direction of a length that is orthogonal to the direction of the thickness, in multiple modes having a plurality of eigenmodes in a direction of a width that is orthogonal to both the direction of the length and the direction of the thickness, and an exiting beam is generated by the plurality of eigenmodes interfering with each other in the direction of the length, and

wherein the exiting beam is made to exit from the optical transmission lines, and the output signal corresponding to the exiting beam is outputted.

30. A method of manufacturing an optical device that connects, by a signal beam, between an externally inputted input signal and an output signal to be outputted,

wherein the optical device comprises

an optical transmission line being sheet-form and including a refractive index distribution such that a highest refractive index part is provided in a direction of a thickness of the sheet and a refractive index does not increase with distance from the highest refractive index part in the direction of the thickness,

wherein a signal beam corresponding to the input signal is made incident on the optical transmission line as an incident beam,

wherein inside the optical transmission line, the incident beam is transmitted, in a direction of a length that is orthogonal to the direction of the thickness, in multiple modes having a plurality of eigenmodes in a direction of a width that is orthogonal to both the direction of the length and the direction of the thickness, and an exiting beam is generated by the plurality of eigenmodes interfering with each other in the direction of the length,

wherein the exiting beam is made to exit from the optical transmission line, and the output signal corresponding to the exiting beam is outputted, and

wherein the optical device manufacturing method comprises:

a first step of preparing a forming die that is made of a material capable of transmitting an energy to be applied to cure a resin of which the optical transmission line is made, and includes a concave portion having at least the same depth as the direction of the thickness of the optical transmission line;

a second step of filling the concave portion with the resin;

a third step of applying the energy in a predetermined quantity to the forming die filled with the resin, from above and below in the direction of the thickness; and

a fourth step of, on the resin cured with a desired refractive index distribution being formed, determining at least a size in the direction of the length and forming a part of connection of

the incident and exiting beams in order to form the resin into the optical transmission line.

31. An optical device manufacturing method according to claim 30, wherein in the third step,

the application of the energy is an application of an ultraviolet ray of a predetermined wavelength, and

wherein in the first step,

the prepared forming die is made of a material that is transparent with respect to the ultraviolet ray of the predetermined wavelength.

32. An optical device manufacturing method according to claim 30, wherein in the third step,

the application of the energy is heating.

33. An optical device manufacturing method according to claim 30, wherein the optical transmission line includes a refractive index distribution such that a central position in the direction of the thickness has the highest refractive index and the refractive index does not increase with distance from the central position.

34. An optical device manufacturing method according to claim 33, wherein the refractive index distribution changes

substantially along a quadratic function.

35. An optical device manufacturing method according to claim 33, wherein the optical transmission line is made of polysilane.

36. An optical device manufacturing method according to claim 35, wherein the optical transmission line is made of polysilane, and the refractive index distribution is provided by an oxygen concentration distribution when the polysilane is cured.

37. An optical device manufacturing method according to claim 30, wherein in the first step,

the forming die includes a concave portion having a size including a plurality of optical transmission lines to be manufactured, and

wherein in the fourth step,

a plurality of optical transmission lines is simultaneously manufactured by cutting the resin.

38. An optical device manufacturing method according to claim 30, wherein in the first step,

the forming die includes a concave portion having a size substantially equal to a size, in the direction of the width, of the optical transmission line to be manufactured, and

wherein in the fourth step,

the size in the direction of the length is determined by cutting the resin.

39. An optical device manufacturing method according to claim 30, wherein in the first step,

the forming die includes a concave portion having a size substantially equal to a size of the optical transmission line to be manufactured, and

wherein in the fourth step,

a wall, of the concave portion, situated in a position where the incident beam and the exiting beam are made incident and made to exit on and from the optical transmission line is removed.

40. An optical device manufacturing method according to claim 30, further comprising a fifth step of releasing the optical transmission line from the forming die either before or after the fourth step.

41. An optical device that is capable of receiving a multiple signal beam where two different wavelengths are superimposed on each other, demultiplexing the multiple signal beam according to the wavelength, and outputting the multiple signal beam as two different signal beams, the optical device comprising:

an optical transmission line being sheet-form and including a refractive index distribution such that a highest refractive index part is provided in a direction of a thickness of the sheet and a refractive index does not increase with distance from the highest refractive index part in the direction of the thickness,

wherein the multiple signal beam is made incident on the optical transmission line as an incident beam,

wherein inside the optical transmission line, the incident beam is transmitted, in a direction of a length that is orthogonal to the direction of the thickness, in multiple modes having a plurality of eigenmodes for each wavelength in a direction of a width that is orthogonal to both the direction of the length and the direction of the thickness, and two exiting beams are generated in different positions in the direction of the width according to the wavelength by the plurality of eigenmodes interfering with each other in the direction of the length with respect to signal beams of the same wavelength, and

wherein the two exiting beams are made to exit from the optical transmission line.

42. An optical device according to claim 41, wherein the two exiting beams are made to exit from positions in the direction of the width where a ratio in light quantity between the two exiting beams is highest.

43. An optical device according to claim 41, wherein the two exiting beams are made to exit from positions in the direction of the width where light quantities of the two exiting beams are lowest.

44. An optical device according to claim 41, wherein the optical transmission line has a size in the direction of the length expressed by a function of a difference between a propagation constant of a 0th-order mode excited in the direction of the width of the optical transmission line and a propagation constant of a primary mode.

45. An optical device according to claim 41, wherein the optical transmission line has a rectangular parallelepiped shape, and has a size in the direction of the length expressed by a function of a basic mode width in the direction of the width, the highest refractive index in the direction of the thickness and a wavelength of a beam transmitted in the multi-mode optical transmission line.

46. An optical device according to claim 41, wherein the optical transmission line includes a refractive index distribution such that a central position in the direction of the thickness has the highest refractive index and the refractive index does not increase with distance from the central position.

47. An optical device according to claim 46, wherein the refractive index distribution changes substantially along a quadratic function.

48. An optical device that is capable of receiving two signal beams having different wavelengths, multiplexing the signal beams and outputting the signal beams as a multiple signal beam where two different wavelengths are superimposed on each other, the optical device comprising

an optical transmission line being sheet-form and including a refractive index distribution such that a highest refractive index part is provided in a direction of a thickness of the sheet and a refractive index does not increase with distance from the highest refractive index part in the direction of the thickness,

wherein the two signal beams are made incident on the optical transmission line as incident beams,

wherein inside the optical transmission line, the incident beam is transmitted, in a direction of a length that is orthogonal to the direction of the thickness, in multiple modes having a plurality of eigenmodes for each wavelength in a direction of a width that is orthogonal to both the direction of the length and the direction of the thickness, and the exiting beam which is a multiple signal beam is generated in the same position in the direction of the width according to the wavelength by the plurality of eigenmodes interfering with each other in the direction of the

length with respect to signal beams of the same wavelength, and

wherein the exiting beam is made to exit from the optical transmission line.

49. An optical device that connects, by a signal beam, between an externally inputted input signal and an output signal to be outputted, the optical device comprising:

an optical transmission line being sheet-form, including a refractive index distribution such that a highest refractive index part is provided in a direction of a thickness of the sheet and a refractive index does not increase with distance from the highest refractive index part in the direction of the thickness, and comprising a first partial optical transmission line and a second partial optical transmission line adjoining in a direction of the width orthogonal to the thickness of the thickness; and

refractive index modulating means capable of changing the refractive index distribution of at least one of the first and second partial optical transmission lines based on an externally supplied control signal,

wherein selection can be made between a first condition in which the incident beam is transmitted by use of only the first partial optical transmission line and a second condition in which the incident beam is transmitted by use of the first and second partial optical transmission lines, based on an operation of the refractive index modulating means,

wherein a signal beam corresponding to the input signal is made incident on the first optical transmission line as the incident beam,

wherein in the first condition,

inside the first optical transmission line, the incident beam is transmitted, in a direction of a length that is orthogonal to the direction of the thickness and the direction of the width, in multiple modes having a plurality of eigenmodes in the direction of the width, the exiting beam is generated by the plurality of eigenmodes interfering with each other in the direction of the length, and

the exiting beam is made to exit from the first optical transmission line and the output signal corresponding to the exiting beam is outputted, and

wherein in the second condition,

inside the first and second optical transmission lines, the incident beam is transmitted, in the direction of the thickness, in multiple modes having a plurality of eigenmodes in the direction of the width, the exiting beam is generated by the plurality of eigenmodes interfering with each other in the direction of the length, and

the exiting beam is made to exit from the second optical transmission line and the output signal corresponding to the exiting beam is outputted.

50. An optical device according to claim 49, wherein the refractive index modulating means

is capable of changing the refractive index distribution of the first multi-mode partial optical transmission line,

in the second condition, makes the refractive index distributions of the first and second multi-mode partial optical transmission lines the same as each other, and

in the first condition, makes a highest refractive index of the first multi-mode partial optical transmission line higher than a highest refractive index of the second multi-mode partial optical transmission line.

51. An optical device according to claim 49, wherein the refractive index modulating means

is capable of changing the refractive index distribution of the second multi-mode partial optical transmission line,

in the second condition, makes the refractive index distributions of the first and second multi-mode partial optical transmission lines the same as each other, and

in the first condition, makes a highest refractive index of the second multi-mode partial optical transmission line lower than a highest refractive index of the first multi-mode optical transmission line.

52. An optical device according to claim 49, wherein the

refractive index modulating means

is capable of changing the refractive index distributions of the first and second multi-mode partial optical transmission lines,

in the second condition, makes the refractive index distributions of the first and second multi-mode partial optical transmission lines the same as each other, and

in the first condition, makes a highest refractive index of the first multi-mode partial optical transmission line higher than a highest refractive index of the second multi-mode partial optical transmission line in the second condition, and makes the highest refractive index of the second multi-mode partial optical transmission line lower than the highest refractive index of the first multi-mode partial optical transmission line in the second condition.

53. An optical device according to claim 49, wherein of the first and second multi-mode optical transmission lines, the optical transmission line whose refractive index distribution is changeable by the refractive index modulating means is made of a polymer exhibiting a thermooptic effect, and

wherein the refractive index modulating means includes a thermal sheet capable of generating/absorbing heat according to the control signal, and

changes the refractive index distribution by changing a

temperature of the optical transmission line by the thermal sheet.

54. An optical device according to claim 49, wherein in the optical transmission line,

a size in the direction of the length is a value that is substantially an odd multiple of the following expression when the basic mode width, in the direction of the width, of the transmission line is W_0, an effective refractive index of a 0th-order mode beam excited in the direction of the width is n_0 and the wavelength of the beam transmitted in the first and second optical transmission lines is λ:

$$\frac{4n_0W_0^2}{\lambda}$$

55. An optical device according to claim 49, wherein the optical transmission line

has a size, in the direction of the width, that is $(1/\sqrt{2})$ times with respect to the direction of the width to which the optical transmission line is added.

56. An optical device according to claim 49, wherein the optical transmission line includes a refractive index distribution such that a central position in the direction of the thickness has the highest refractive index and the refractive index does not increase with distance from the central position.

57. An optical device according to claim 56, wherein the refractive index distributions change substantially along a quadratic function.

58. An optical device for changing a distance between a number, N (N=2,3,4,...), of signal beams disposed on a straight line,

wherein a number, N, of optical transmission lines are disposed on the straight line, the optical transmission lines being sheet-form and including a refractive index distribution such that a highest refractive index part is provided in a direction of a thickness of the sheet and a refractive index does not increase with distance from the highest refractive index part in the direction of the thickness,

wherein the signal beams are made incident on the optical transmission lines as incident beams,

wherein inside the optical transmission lines, the incident beam is transmitted, in a direction of a length that is orthogonal to the direction of the thickness, in multiple modes having a plurality of eigenmodes in a direction of a width that is orthogonal to both the direction of the length and the direction of the thickness, and exiting beams are generated in positions different from positions where the incident beams are incident on the optical transmission lines in the direction of the width by the plurality of eigenmodes interfering with each other in the direction of the

length, and

wherein the exiting beams are made to exit from the optical transmission lines as the signal beams.

59. An optical device according to claim 58, wherein the optical transmission lines include:

an incident surface for making the incident beams incident; and

an exit surface for making the exiting beams exit, and

wherein the incident beams are made incident on given positions in the direction of the width on the incident surface and the exiting beams are generated in positions, on the exit surface, whose positions in the direction of the width are symmetrical to the incident positions of the incident beams with respect to a center in the direction of the width.

60. An optical device according to claim 58, wherein the optical device increases the distance between the signal beams.

61. An optical device according to claim 58, further comprising a sheet-form incident side optical transmission line, and the optical transmission line is a 1×N optical splitting device that splits one incident beam into a number, N, of beams and connects the number, N, of exiting beams into which the incident beam is split, to the optical transmission lines as the signal beams.

62. An optical device for changing a position of a signal beam, the optical device comprising

a plurality of optical transmission lines being sheet-form and including a refractive index distribution such that a highest refractive index part is provided in a direction of a thickness of the sheet and a refractive index does not increase with distance from the highest refractive index part in the direction of the thickness,

wherein the plurality of optical transmission lines are connected in multiple stages so that an exiting beam having exited from one of the optical transmission lines becomes an incident beam to be made incident on another one of the optical transmission lines,

wherein the signal beam is made incident on the optical transmission line as the incident beam,

wherein inside the optical transmission lines, the incident beam is transmitted, in a direction of a length that is orthogonal to the direction of the thickness, in multiple modes having a plurality of eigenmodes in a direction of a width that is orthogonal to both the direction of the length and the direction of the thickness, and the exiting beam is generated in a position different from a position where the incident beam is incident on the optical transmission lines in the direction of the width by the plurality of eigenmodes interfering with each other in the direction of the

length, and

wherein the exiting beam is made to exit from the optical transmission lines as the signal beam.

63. An optical device according to claim 62, wherein the signal beam is a number, N (N=2,3,4,...), of signal beams disposed on a straight line,

wherein a number, N, of optical transmission lines are disposed on the straight line to change a distance between the number, N, of signal beams, the optical transmission lines being sheet-form and including a refractive index distribution such that a highest refractive index part is provided in a direction of a thickness of the sheet and a refractive index does not increase with distance from the highest refractive index part in the direction of the thickness,

wherein the signal beams are made incident on the optical transmission lines as the incident beams,

wherein inside the optical transmission lines, the incident beams are transmitted, in the direction of the length that is orthogonal to the direction of the thickness, in multiple modes having a plurality of eigenmodes in the direction of the width that is orthogonal to both the direction of the length and the direction of the thickness, and exiting beams are generated in positions different from positions where the incident beams are incident on the optical transmission lines in the direction of

the width by the plurality of eigenmodes interfering with each other in the direction of the length, and

wherein the exiting beams are made to exit from the optical transmission lines as the signal beam.

64. An optical device that connects, by a signal beam, between an externally inputted input signal and an output signal to be outputted, the optical device comprising:

a sheet-form optical transmission line being sheet-form and including a refractive index distribution such that a highest refractive index part is provided in a direction of a thickness of the sheet and a refractive index does not increase with distance from the highest refractive index part in the direction of the thickness;

an incident side optical transmission line that transmits the incident beam corresponding to the input signal so as to be incident on the sheet-form optical transmission line;

an incident side beam converter that connects the incident side optical transmission line and the sheet-form optical transmission line and converts a mode field of the incident side optical transmission line so that it can be incident on the sheet-form optical transmission line;

an exit side optical transmission line that transmits the exiting beam from the sheet-form optical transmission line so as to exit as the output signal; and

an exit side beam converter that connects the exit side optical transmission line and the sheet-form optical transmission line and converts a mode field of the sheet-form optical transmission line so that it can be incident on the exit side optical transmission line,

wherein the signal beam exiting from the incident side beam converter is made incident on the sheet-form optical transmission line as the incident beam,

wherein inside the sheet-form optical transmission line, the incident beam is transmitted, in a direction of a length that is orthogonal to the direction of the thickness, in multiple modes having a plurality of eigenmodes in a direction of a width that is orthogonal to both the direction of the length and the direction of the thickness, and the exiting beam is generated by the plurality of eigenmodes interfering with each other in the direction of the length, and

wherein the exiting beam is made to exit from the sheet-form optical transmission line and made incident on the exit side beam converter.

65. An optical device according to claim 64, wherein the incident side beam converter

is a lens element having a refractive index distribution such that a highest refractive index is provided at a center and a refractive index decreases with distance from the center, and

is disposed in the same numbers as the signal beams that are made incident on the sheet-form optical transmission line.

66. An optical device according to claim 65, wherein the incident side beam converter

includes the refractive index distribution such that a change in refractive index between the center and a periphery gradually increases from a side of the incident side optical transmission line toward a side of the sheet-form optical transmission line.

67. An optical device according to claim 64, wherein the incident side beam converter

is a slab waveguide having a refractive index distribution such that the highest refractive index is provided in a central portion, in a direction parallel to the direction of the thickness, of the sheet-form optical transmission line and the refractive index decreases with distance from the central portion, and

is disposed in the same numbers as the signal beams that are made incident on the sheet-form optical transmission line.

68. An optical device according to claim 67, wherein the slab waveguide has a configuration such that a size in the direction of the width decreases toward a part of connection with the sheet-form optical transmission line.

69. An optical device according to claim 67, wherein the incident side beam converter is formed integrally with the sheet-form optical transmission line.

70. An optical device according to claim 64, wherein the incident side beam converter

is an optical transmission line having a refractive index distribution such that a highest refractive index is provided in a central portion, in a direction parallel to the direction of the thickness and a direction parallel to the direction of the width, of the sheet-form optical transmission line and the refractive index decreases with distance from the central portion, and

the number of incident side beam converters disposed for the sheet-form optical transmission line is one.

71. An optical device according to claim 64, wherein the exit side beam converter

is a lens element having a refractive index distribution such that a highest refractive index is provided at a center and a refractive index decreases with distance from the center, and

is disposed in the same numbers as the signal beams exiting from the sheet-form optical transmission line.

72. An optical device according to claim 65, wherein the

exit side optical transmission line

is an optical fiber having a refractive index distribution such that a highest refractive index is provided at a center and a refractive index decreases with distance from the center, and

wherein the exit side beam converter

includes the refractive index distribution such that a change in refractive index between the center and a periphery gradually increases from a side of the exit side optical transmission line toward a side of the sheet-form optical transmission line.

73. An optical device according to claim 64, wherein the exit side beam converter

is a slab waveguide having a refractive index distribution such that the highest refractive index is provided in a central portion, in a direction parallel to the direction of the thickness, of the sheet-form optical transmission line and the refractive index decreases with distance from the central portion, and

is disposed in the same numbers as the signal beams exiting from the sheet-form optical transmission line.

74. An optical device according to claim 73, wherein the slab waveguide has a configuration such that a size in the direction of the width decreases toward a part of connection with the sheet-form optical transmission line.

75. An optical device according to claim 73, wherein the exit side beam converter is formed integrally with the sheet-form optical transmission line.

76. An optical device according to claim 64, wherein the exit side beam converter

is an optical transmission line having a refractive index distribution such that a highest refractive index is provided in a central portion, in a direction parallel to the direction of the thickness and a direction parallel to the direction of the width, of the sheet-form optical transmission line and the refractive index decreases with distance from the central portion, and

the number of exit side beam converters disposed for the sheet-form optical transmission line is one.

77. A method of manufacturing an optical device that connects, by a signal beam, between an externally inputted input signal and an output signal to be outputted,

the optical device comprising:

a sheet-form optical transmission line being sheet-form and including a refractive index distribution such that a highest refractive index part is provided in a direction of a thickness of the sheet and a refractive index does not increase with distance from the highest refractive index part in the direction of the

thickness;

an incident side optical transmission line that transmits the incident beam corresponding to the input signal so as to be incident on the sheet-form optical transmission line;

an incident side beam converter that connects the incident side optical transmission line and the sheet-form optical transmission line and converts a mode field of the incident side optical transmission line so that it can be incident on the sheet-form optical transmission line;

an exit side optical transmission line that transmits the exiting beam from the sheet-form optical transmission line so as to exit as the output signal; and

an exit side beam converter that connects the exit side optical transmission line and the sheet-form optical transmission line and converts a mode field of the sheet-form optical transmission line so that it can be incident on the exit side optical transmission line,

the optical device manufacturing method comprising: a first step of preparing a forming die that has a concave portion corresponding to the sheet-form optical transmission line and at least one of the incident side beam converter and the exit side beam converter and is made of a material capable of transmitting an energy to be applied to cure a resin of which the sheet-form optical transmission line is made;

a second step of filling the concave portion with the resin;

a third step of applying the energy in a predetermined quantity to the forming die filled with the resin, from above and below in the direction of the thickness to form a desired refractive index distribution by curing the resin; and

a fourth step of, when the incident side beam converter and the exit side beam converter not formed in the concave portion are present, connecting the converters to the cured resin, and further, connecting the incident side optical transmission line and the exit side optical transmission line.

78. An optical device manufacturing method according to claim 77, wherein the application of the energy is an application of an ultraviolet ray of a predetermined wavelength, and

wherein the forming die is made of a material that is transparent with respect to the ultraviolet ray of the predetermined wavelength.

79. An optical device manufacturing method according to claim 30, wherein the application of the energy is heating.

80. An optical device manufacturing method according to claim 77, comprising a fifth step of releasing the cured resin from the forming die prior to the fourth step.

81. An optical device manufacturing method according to

claim 80, wherein in the fourth step,

when the incident side beam converter and the exit side beam converter not formed in the forming die are present, the converters are connected to the cured resin, and further, when the incident side optical transmission line and the exit side optical transmission line are connected together, the optical transmission lines are disposed on a substrate where a positioning portion for positioning the optical transmission lines is formed.

82. An optical device manufacturing method according to claim 77, wherein in the first step,

the forming die includes a positioning portion for positioning at least one of the incident side optical transmission line and the exit side optical transmission line, and

wherein in the fourth step,

the optical transmission lines are disposed on the forming die where the positioning portion is formed.

83. An optical device manufacturing method according to claim 77, wherein the incident side optical transmission line is an optical fiber.

84. An optical device manufacturing method according to claim 77, wherein the exit side optical transmission line is an optical fiber.

85. An optical device that transmits an externally incident signal beam and makes the transmitted signal beam to exit to an outside, the optical device comprising

an optical transmission line including a refractive index distribution in a first direction and being capable of transmitting the signal beam with a plurality of optical paths in a second direction orthogonal to the first direction,

wherein at least one of an optical axis of the signal beam incident on the optical transmission line and an optical axis of the signal beam exiting from the optical transmission line is not parallel to the second direction, and

wherein a phase difference, at the time of incidence on the optical transmission line, between the two optical paths, of the plurality of optical paths, incident on the optical transmission line symmetrically to each other with respect to the optical axis of the signal beam and a phase difference, at the time of exit from the optical transmission line, between the two optical paths are the same.

86. An optical device according to claim 85, comprising: an incident portion for making the signal beam incident on the optical transmission line; and

an exit portion for making the signal beam to exit from the optical transmission line,

wherein at least one of the incident portion and the exit

portion is coupled to the optical transmission line so that the optical axis of the signal beam transmitted inside is in a direction not parallel to the second direction.

87. An optical device according to claim 86, wherein at least one of the incident portion and the exit portion is coupled to the optical transmission line so that the optical axis of the signal beam transmitted inside is orthogonal to the second direction.

88. An optical device according to claim 86, wherein an optical path length difference between the two optical axes is equal to an integral multiple of a wavelength of the transmitted signal beam.

89. An optical device according to claim 88, wherein the two optical axes include a number, m (m=1,2,3,...), of optical path length difference generating portions where the optical path length difference is caused, and

wherein a sum of the optical path length differences caused in the number, m, of optical path length difference generating portions is equal to a natural multiple of the wavelength of the signal beam.

90. An optical device according to claim 89, wherein the

optical transmission line

is a sheet-form optical transmission line capable of trapping the signal beam in the first direction, and includes a refractive index distribution such that a refractive index in a central portion where a thickness in the first direction is half is the highest and the refractive index does not increase with distance from the central portion in the first direction.

91. An optical device according to claim 90, wherein the sheet-form optical transmission line includes:

a first reflecting surface for bending an optical axis of a signal beam incident from a direction not parallel to the second direction, in the second direction; and

a second reflecting surface for bending an optical axis of a signal beam transmitted in the second direction, in the direction not parallel to the second direction,

wherein the optical path length difference generating portion is a portion where refractive index histories of the two optical paths reflected by the first and second reflecting surfaces are different from each other.

92. An optical device according to claim 90, wherein in the sheet-form optical transmission line,

a physical optical path length from a position where all of the signal beam is bent in the second direction by the first

reflecting surface to a position immediately before all of the signal beam is incident on the second reflecting surface is equal to j (j=0,1,2,3,...) times a period of meandering of an optical path transmitted while meandering based on the refractive index distribution.

93. An optical device according to claim 88, wherein the two optical paths include a number, n (n=2,3,4,...) of optical path length difference generating portions where an optical path length difference is caused, and

wherein a sum of the optical path length differences caused in the number, n, of optical path length difference generating portions is zero.

94. An optical device according to claim 93, wherein the optical transmission line

is a sheet-form optical transmission line capable of trapping the signal beam in the first direction, and includes a refractive index distribution such that a refractive index in a central portion where a thickness in the first direction is half is the highest and the refractive index does not increase with distance from the central portion in the first direction.

95. An optical device according to claim 94, wherein the sheet-form optical transmission line includes:

a first reflecting surface for bending an optical axis of a signal beam incident from a direction not parallel to the second direction, in the second direction; and

a second reflecting surface for bending an optical axis of a signal beam transmitted in the second direction, in the direction not parallel to the second direction,

wherein the optical path length difference generating portions are portions where refractive index histories of the two optical paths reflected by the first and second reflecting surfaces are different from each other.

96. An optical device according to claim 94, wherein in the sheet-form optical transmission line,

a physical optical path length from a position where all of the signal beam is bent in the second direction by the first reflecting surface to a position immediately before all of the signal beam is incident on the second reflecting surface is equal to (j+0.5) (j=0,1,2,3,...) times a period of meandering of an optical path transmitted while meandering based on the refractive index distribution.

97. An optical device according to claim 86, wherein an optical path length difference between the two optical paths is zero.

98. An optical device according to claim 97, wherein the two optical paths include a number, n (n=2,3,4,...) of optical path length difference generating portions where an optical path length difference is caused, and

wherein a sum of the optical path length differences caused in the number, n, of optical path length difference generating portions is zero.

99. An optical device according to claim 98, wherein the optical transmission line

is a sheet-form optical transmission line capable of trapping the signal beam in the first direction, and includes a refractive index distribution such that a refractive index in a central portion where a thickness in the first direction is half is the highest and the refractive index does not increase with distance from the central portion in the first direction.

100. An optical device according to claim 99, wherein the sheet-form optical transmission line includes:

a first reflecting surface for bending an optical axis of a signal beam incident from a direction not parallel to the second direction, in the second direction; and

a second reflecting surface for bending an optical axis of a signal beam transmitted in the second direction, in the direction not parallel to the second direction,

wherein the optical path length difference generating portions are portions where refractive index histories of the two optical paths reflected by the first and second reflecting surfaces are different from each other.

101. An optical device according to claim 99, wherein in the sheet-form optical transmission line,

a physical optical path length from a position where all of the signal beam is bent in the second direction by the first reflecting surface to a position immediately before all of the signal beam is incident on the second reflecting surface is equal to (j+0.5) (j=0,1,2,3,...) times a period of meandering of an optical path transmitted while meandering based on the refractive index distribution.

102. An optical device according to claim 97, wherein the two optical paths do not have a portion where the optical path length difference is caused.

103. An optical device according to claim 102, wherein the optical transmission line

is a sheet-form optical transmission line capable of trapping the signal beam in the first direction, and includes a refractive index distribution such that a refractive index in a central portion where a thickness in the first direction is half is the highest

and the refractive index does not increase with distance from the central portion in the first direction.

104. An optical device according to claim 103, wherein the sheet-form optical transmission line includes:

a first reflecting surface for bending an optical axis of a signal beam incident from a direction not parallel to the second direction, in the second direction; and

a second reflecting surface for bending an optical axis of a signal beam transmitted in the second direction, in the direction not parallel to the second direction,

wherein a physical optical path length between the first reflecting surface and the second reflecting surface in the central portion is equal to j/2 (j=0,1,2,3,...) times a period of meandering of an optical path transmitted while meandering based on the refractive index distribution, and

wherein the signal beam is condensed into a line parallel to a third direction orthogonal to both the first direction and the second direction in the central portion where the thickness, in the first direction, of the optical transmission line is half on the first reflecting surface and the second reflecting surface.

105. An optical device that transmits an externally incident signal beam and makes the transmitted signal beam exit from a predetermined position to an outside by a multi-mode

interference, the optical device comprising:

a sheet-form optical transmission line including a refractive index distribution in a first direction, being capable of transmitting the signal beam in a second direction orthogonal to the first direction, and being capable of trapping the signal beam in the first direction;

a number, M (M=1,2,3,...), of incident portions for making the signal beam incident on the sheet-form optical transmission line; and

a number, N (N=1,2,3,...), of exit portions for making the signal beam exit from the sheet-form optical transmission line,

wherein the number, M, of incident portions and the number, N, of exit portions include at least one nonparallel incident and exit portion that is coupled to the sheet-form optical transmission line in a direction where an optical axis of the signal beam transmitted inside is not parallel to the second direction,

wherein between two optical paths incident on the sheet-form optical transmission line symmetrically to each other with respect to the optical axis of the signal beam, of a plurality of optical paths of the signal beam transmitted between the nonparallel incident and exit portion and the corresponding incident or exit portion, a phase difference at the time of incidence on the sheet-form optical transmission line and a phase difference at the time of exit from the sheet-form optical transmission line are the same, and

wherein the number, M, of incident portions and the number, N, of exit portions are all disposed in positions satisfying a predetermined condition of a self-imaging principle of the multi-mode interference.

106. An optical device according to claim 105, wherein the nonparallel incident and exit portion is coupled to the optical transmission line so that the optical axis of the signal beam transmitted inside is orthogonal to the second direction.

107. An optical device according to claim 105, wherein an optical path length difference between the two optical paths is equal to an integral multiple of a wavelength of the transmitted signal beam.

108. An optical device according to claim 107, wherein the two optical paths include a number, m (m=1,2,3,...) of optical path length difference generating portions where the optical path length difference is caused, and

wherein a sum of the optical path length differences caused in the number, m, of optical path length difference generating portions is equal to a natural multiple of the wavelength of the signal beam.

109. An optical device according to claim 108, wherein the

sheet-form optical transmission line

includes a refractive index distribution such that a refractive index in a central portion where a thickness in the first direction is half is the highest and the refractive index does not increase with distance from the central portion in the first direction.

110. An optical device according to claim 109, wherein the sheet-form optical transmission line includes:

a first reflecting surface for bending an optical axis of a signal beam incident from a direction not parallel to the second direction, in the second direction; and

a second reflecting surface for bending an optical axis of a signal beam transmitted in the second direction, in the direction not parallel to the second direction,

wherein the optical path length difference generating portion is a portion where refractive index histories of the two optical paths reflected by the first and second reflecting surfaces are different from each other.

111. An optical device according to claim 109, wherein in the sheet-form optical transmission line,

a physical optical path length from a position where all of the signal beam is bent in the second direction by the first reflecting surface to a position immediately before all of the

signal beam is incident on the second reflecting surface is equal to j (j=0,1,2,3,...) times a period of meandering of an optical path transmitted while meandering based on the refractive index distribution.

112. An optical device according to claim 107, wherein the two optical paths include a number, n (n=2,3,4,...) of optical path length difference generating portions where the optical path length difference is caused, and

wherein a sum of the optical path length differences caused in the number, n, of optical path length difference generating portions is zero.

113. An optical device according to claim 112, wherein the sheet-form optical transmission line

includes a refractive index distribution such that a refractive index in a central portion where a thickness in the first direction is half is the highest and the refractive index does not increase with distance from the central portion in the first direction.

114. An optical device according to claim 113, wherein the sheet-form optical transmission line includes:

a first reflecting surface for bending an optical axis of a signal beam incident from a direction not parallel to the second

direction, in the second direction; and

a second reflecting surface for bending an optical axis of a signal beam transmitted in the second direction, in the direction not parallel to the second direction,

wherein the optical path length difference generating portions are portions where refractive index histories of the two optical paths reflected by the first and second reflecting surfaces are different from each other.

115. An optical device according to claim 113, wherein in the sheet-form optical transmission line,

a physical optical path length from a position where all of the signal beam is bent in the second direction by the first reflecting surface to a position immediately before all of the signal beam is incident on the second reflecting surface is equal to (j+0.5) (j=0,1,2,3,...) times a period of meandering of an optical path transmitted while meandering based on the refractive index distribution.

116. An optical device according to claim 105, wherein an optical path length difference between the two optical paths is zero.

117. An optical device according to claim 116, wherein the two optical paths include a number, n (n=2,3,4,...) of optical

path length difference generating portions where the optical path length difference is caused, and

wherein a sum of the optical path length differences caused in the number, n, of optical path length difference generating portions is zero.

118. An optical device according to claim 117, wherein the sheet-form optical transmission line

includes a refractive index distribution such that a refractive index in a central portion where a thickness in the first direction is half is the highest and the refractive index does not increase with distance from the central portion in the first direction.

119. An optical device according to claim 118, wherein the sheet-form optical transmission line includes:

a first reflecting surface for bending an optical axis of a signal beam incident from a direction not parallel to the second direction, in the second direction; and

a second reflecting surface for bending an optical axis of a signal beam transmitted in the second direction, in the direction not parallel to the second direction,

wherein the optical path length difference generating portions are portions where refractive index histories of the two optical paths reflected by the first and second reflecting surfaces

are different from each other.

120. An optical device according to claim 118, wherein in the sheet-form optical transmission line,

a physical optical path length from a position where all of the signal beam is bent in the second direction by the first reflecting surface to a position immediately before all of the signal beam is incident on the second reflecting surface is equal to (j+0.5) (j=0,1,2,3,...) times a period of meandering of an optical path transmitted while meandering based on the refractive index distribution.

121. An optical device according to claim 116, wherein the two optical paths do not have a portion where the optical path length difference is caused.

122. An optical device according to claim 121, wherein the sheet-form optical transmission line

includes a refractive index distribution such that a refractive index in a central portion where a thickness in the first direction is half is the highest and the refractive index does not increase with distance from the central portion in the first direction.

123. An optical device according to claim 122, wherein the

sheet-form optical transmission line includes:

a first reflecting surface for bending an optical axis of a signal beam incident from a direction not parallel to the second direction, in the second direction; and

a second reflecting surface for bending an optical axis of a signal beam transmitted in the second direction, in the direction not parallel to the second direction,

wherein a physical optical path length between the first reflecting surface and the second reflecting surface in the central portion is equal to j/2 (j=0,1,2,3,...) times a period of meandering of an optical path transmitted while meandering based on the refractive index distribution, and

wherein the signal beam is condensed into a line parallel to a third direction orthogonal to both the first direction and the second direction in the central portion where the thickness, in the first direction, of the optical transmission line is half on the first reflecting surface and the second reflecting surface.